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Origin of hydrophobins and the constant “*k*” in Henry’s Law govern the volume of foam formed by primary gushing of beer

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Introduction:

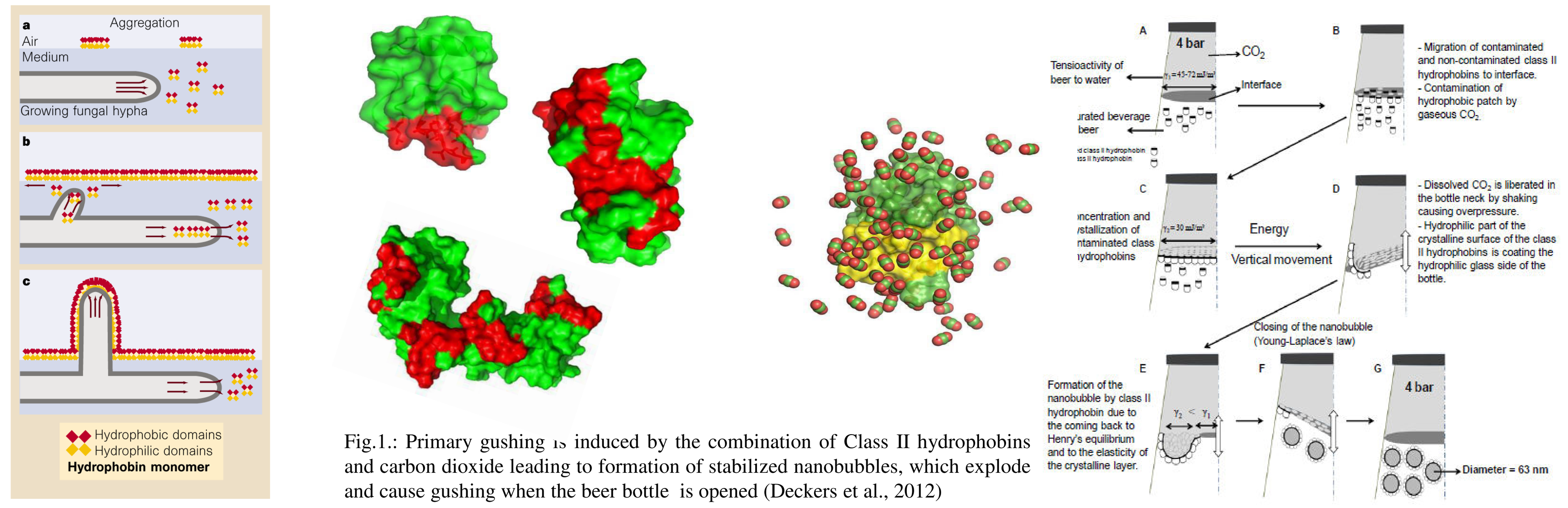

Fig.1.: Primary gushing is induced by the combination of Class II hydrophobins and carbon dioxide leading to formation of stabilized nanobubbles, which explode and cause gushing when the beer bottle is opened (Deckers et al., 2012)

Material and methodology:

Material:
Class II hydrophobins (HFBII) isolated from *Trichoderma ressei* were used.

Methods:
Two experimental methods were used: conventional MCT (Modified Carlsberg test) (Radau et al., 1995; Garbe et al., 2007) and DC (Desaturation cell) (Novak et al., 2015) – a new apparatus built to study gushing. DC is based on Carlsberg (Vaag et al., 1993) and Weinhenstpaher test (Donhauser et al., 1990). In this apparatus all parametres (pressure inside in DC, pressure release, timing of presure release etc.) can be fixed, which is increasing the reproducibility of this method.

Modified Carlsberg test (MCT):

- The matrix (water: CO_2 = 7g)l) is replaced by defined amount of sample
- Three days of horizional shaking
- Evaluation by subtracting the weight loss

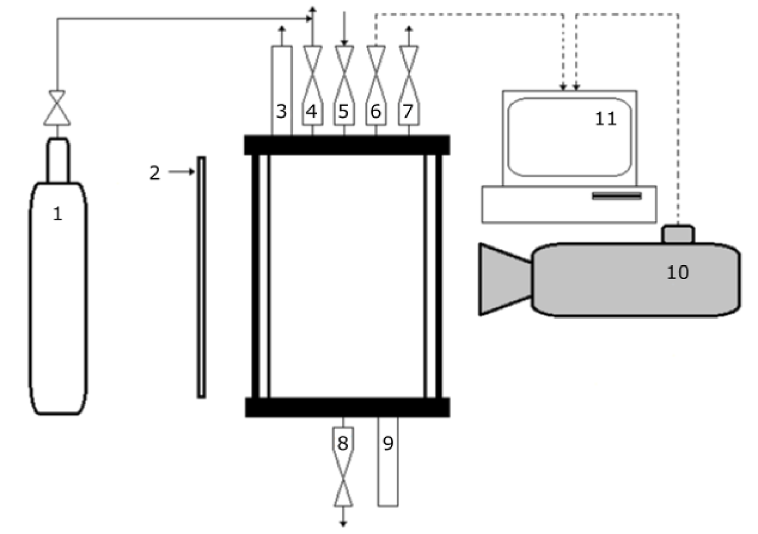

Fig.2.: Experimental apparatus and its components: (1) gas pressure cylinder with CO2 (2) illumination system; (3) safety valve (4) gas feed (5)liquid feed (6) pressure probe (7) gas exit valve (8) emptying valve (9)thermometer (10) video camera and (11) personal computer for data acquisition and data treatment

Desaturation cell (DC):

- Sample (0.5 L) placed into the DC
- Valves closed
- Horizontal shaking of DC with saturation (15 min) and without saturation (45 min)
- Placement of DC to vertical positon
- Controlled drop of pressure in DC by solenoid valve
- Evaluation by manual reading of the foam height ($h = f(t)$) and pressure change in time ($p = f(t)$) – gushing characteristic:

Foam growth rate:

$$r = \frac{\Delta h}{\Delta t}\left[\frac{cm}{s}\right]$$

Results and Discussion:

Physico-chemical influences of primary gushing:

Chemical:

Hydrophobin concentration - with the increasing hydrophobins level gushing is stimulated. From the concentration (250 µg/L) the overfoaming volume did not increase. In the bottle (depends of the bottle neck diameter) each hydrophobin has a limit concentration provoking maximum gushing.

Physical:

Equlibrium:

Henry´s Law: $p = k_H . c$

Non - equilibrium sources (Bartovská and Šišková 2010) :
(1) the medium is an internal source of CO_2 (product of reaction or fermentation)
(2) pressure drop over the saturated liquid (desaturation by bottle opening)
(3) change of the temperature (Henry's constant)

All these three conditions influence the final gushing volume. Theoretically, when the hydrophobins level in the liquid is reached its limit, the final gushing volume will be controlled by pressure and temperature before the opening.

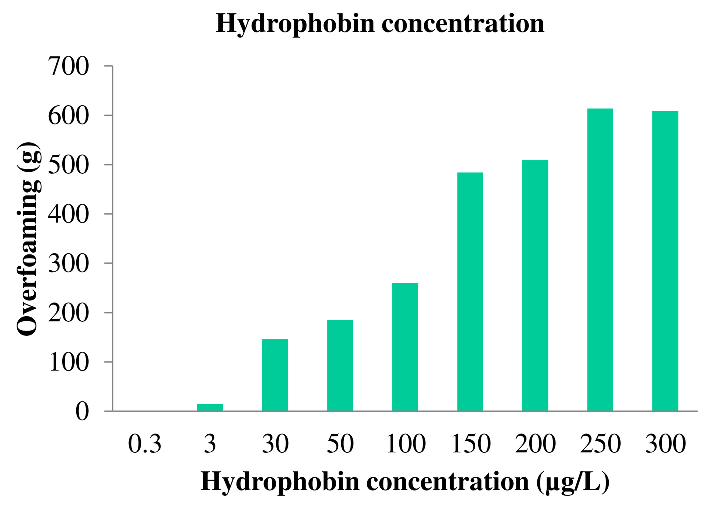

Fig.3.: Gushing volume caused by different hydrophobin concentration (measured by MCT)

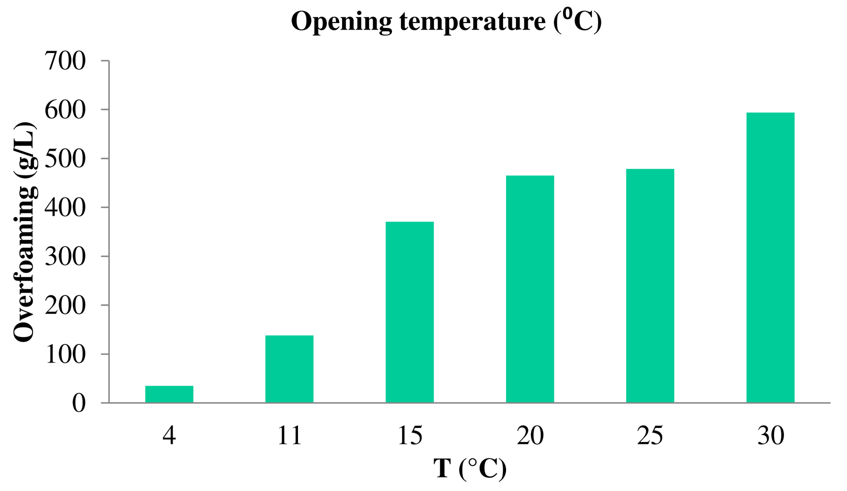

Fig.4.: Gushing volume of different opening temperature (c_{HFBII} = 150 µg/L) (measured by MCT)

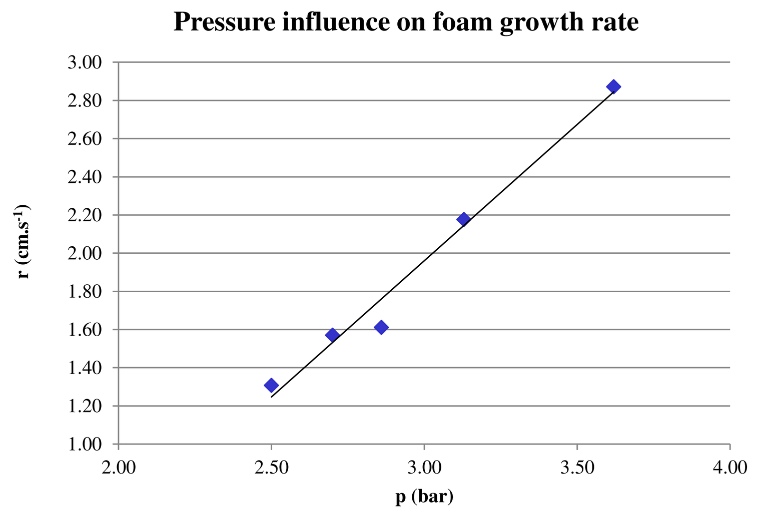

Fig.5.: Gushing foam growth rate characteristic of different pressure level (measured by DC): the intensity of foaming is directly proportional to the pressure used for the saturation of the solution. The maximum tested pressure (3.8 bar) was limited by the apparatus (DC).

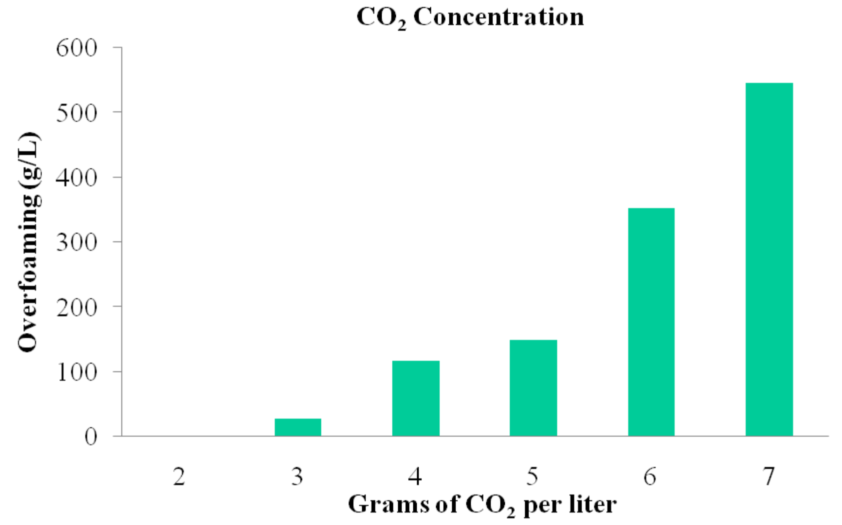

Fig.6.: Gushing volume of CO_2 content (c_{HFBII} = 150 µg/L) (measured by MCT)

Conclusion:

Our results shows that after reaching the limit concentration of hydrophobins in the liquid, the gushing volume is influenced only by the pressure (concentration of CO_2) and Henry's constant as a function of temperature.

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